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Where Art and Science Meet

Genetic Engineering in Contemporary Art

ART AND SCIENCE

In the twentieth century, there was probably no more popular scientific term than «gene» and no other scientific discipline's images and visual metaphors achieved the status of all-pervasive cultural icons like those of molecular biology.[1] The significance ascribed to genes, in anticipation of mapping and marketing them, extends far beyond their immediate role in heredity and development processes. The form of pictorial representation of the human genome in the shape of a double helix and images of the twenty-three pairs of human chromosomes are today no longer neutral descriptions of human genetic processes but rather have advanced to the status of ornaments and vehicles of a mythological and religious meaning of «life itself».[2] Already around 1900, early representatives of the young discipline of genetics exhibited a tendency to indulge in utopian rhetoric, conjuring up visions of a «biological art of engineering» or a «technology of living organisms», which did not confine itself to the shaping of plants and animals but aspired to setting new yardsticks for human coexistence and the organisation of human society.[3] Then, as now, the heralds of this «biological revolution» were predicting nothing less than a second creation; this time, however, it would be an artificially created bioindustrial nature, which would replace the original concept of evolution.

In contemporary art, many exhibitions[4] in recent years have taken as their theme the effects of this «biological revolution» on people's self-image and on the multi-layered interrelations between art and genetics.[5] However, in contrast to the first encounters between art and genetics, which began in the early twentieth century with art's visual and affirmative engagement with genetics, today these «scientific» images are decoded through the linking of art and the images of the life sciences and a new way of reading them results. Artists take the terminology of the sphere of art and apply it to the technically generated images of molecular biology or other life sciences, question their claim to «objectivity» and «truth», and render them recognisable as a space where other fields of knowledge and cultural areas are also inscribed. With the aid of an *iconography of images from science*, the attempt is made to decipher the cultural codes that these images transport additionally.

BIOLOGY AND IMAGE FORM

Long before the discovery of deoxyribonucleic acid (DNA) or the formulation of Charles Darwin's theory of evolution[6], artists rejected the — often postulated — division between art and science, not least on the grounds that scientists were often guided by aesthetic aspects in their research.[7] Darwin's publications, On the Origin of Species (1859)[8] and The Descent of Man (1871),[9] are based on skilfully applied photographic strategies, thus it was only natural that, in turn, they elicited artistic responses and reflections. The German biologist, Ernst Haeckel, for example, promoted Darwin's theories very successfully in the period 1899–1904 with his beautiful lithographs of radiolarians, marine protozoans.[10] In several of his works, Paul Klee derived his inspiration from the theory of evolution[11] and D'Arcy Wentworth Thompson's book, On Growth and Form (1917),[12] aroused the interest of several abstract expressionist artists.[13]

The term gene was introduced in the literature in the early years of the twentieth century, although it would take another fifty years before genes began to take on contours. In 1900, three articles appeared which cited the work of a hitherto unknown monk named Gregor Johann Mendel. The authors were Hugo de Vries, Carl Correns, and Erich von Tschermak[14] and the articles concerned Mendel's careful investigations on hybridisation of garden pea plants in the grounds of his monastery. Allegedly independently of one another, de Vries, Correns and Tschermak had «rediscovered» Mendel's ideas on heredity, which he had formulated in the second half of the nineteenth century.[15] Mendel's own published

Plate 1: Suzanne Anker, Zoosemiotics (Primates), 1993

Plate. 2: Suzanne Anker, Zoosemiotics (Primates) (1993), detail.

findings[16] were largely ignored during his lifetime; unlike the three papers published in 1900, the same year that Max Planck discovered the quantum effect. The three papers laid the foundations of a new scientific discipline that, in 1906, was given the name «genetics»[17] and less than a century later, rose to become the leading science in Western society.

For nineteenth-century biologists, the concept of heredity comprised both the «transmission of developmental properties through reproduction as well as the development of properties into specific adult traits».[18] However, at the turn of the twentieth century a fundamental change was underway whereby the study of the heredity and variation of organisms began to separate off from the study of embryos and their development to form two separate branches of biology.[19] Henceforth, genetics and embryology went their separate ways, each developing their own specific terminology and spawning their own specialist journals and literature. To begin with, genetic research concentrated on investigating the transmission of traits to offspring but soon came to the conclusion that this process must depend on the existence of elements inside the cell. However, when the U.S. American embryologist Thomas Hunt Morgan[20] claimed in 1933 that «There is no consensus opinion amongst geneticists as to what the genes are — whether they are real or purely fictitious»[21], for the majority of his geneticist colleagues genes were already «real, material entities — the biological analogue of the molecules and atoms of physical science.»[22]

In the early 1940s, geneticists established the chemical identity of genes and proved that these molecules are constituted of DNA. Nearly ten years later, DNA was identified as the material carrying specific biological traits in bacteria. From this point, it was but a short step to an optical representation, which gave DNA a «face»: in 1953, James D. Watson and Frances Crick published their model of the molecular structure of DNA in the form of a double helix. The model proved that genes are the units of inheritance and this is encoded in sequences of base pairs of chromosomes arranged linearly along the strands of DNA. It became clear that this nucleic acid, that is, real molecules, carries the genetic information of an organism and not, as previously thought, proteins. Today the model of the double helix is found in every text book on genetics and functions as a so-called «black box.»[23] Prised out of the historic and social context of its development, in the following years the double helix became the most fundamental scientific fact of genetics and a symbol of «the stuff that life is made of» in popular culture.

ART AND GENETICS

Here, art's field of action ranges from the virtual images of the Human Genome Project,[24] computer-generated visualizations of models in molecular biology and bio-

Plate 3: Suzanne Anker, Sugar Daddy: The Genetics of Oedipus. (1992)

Plate 4: Suzanne Anker, Code X: genome. (2000)

informatics, to real applications of advanced genetics, and attempts by artists to simulate evolutionary processes. Perhaps more than any other contemporary artist, Suzanne Anker, professor and director of the Seminar for Art History at the School of Visual Arts in New York, has sought a dialogue between art, genetics, and aesthetic visualisation in her many works. In the installation *Zoosemiotics (Primates)* of 1993, Anker crosses her own visual language with that of the imagery of genetics,[25] focussing on the visual metaphor of the chromosome, a metaphor of molecular biology second only to the double helix in popularity. Six rows of carefully arranged sculpted metal chromosome pairs are mounted on a wall and in front of these stands a glass vessel filled with water on a slim stand. Seen through the vessel, the chromosomes appear distorted. The intention is not to visualise the diversity and forms of the chromosomes but rather to instruct the eye in the simple, analogue, optical technique of magnification through a glass filled with water. By utilizing the laws of optics, Anker draws attention subtly to the production of visual patterns of abstract content with regard to their historicity. Models, metaphors, and visualisations are an integral part of science; the forms they take are always linked to their particular period and its dominant vocabulary of style. Thus, in Anker's understanding, the visual language of contemporary science, which has access to the most advanced imaging techniques, is neither «objective» or «neutral», and for her the task of the artist is to highlight the functions that are inscribed in the visual metaphors of science. Here, the use of optical distortion produced by a water-filled vessel takes on the task of demonstrating how the visualisation of scientific images depends on the human subject, their dependence on optical media, and the specific conventions of perception obtaining in a particular epoch.[26]

Anker also plays on human perception in her installation *Sugar Daddy: The Genetics of Oedipus* (1992). Shimmering blue velvet, draped in heavy folds to form a dense uneven surface, is the background for pairs of chromosomes made of sugar. Only on closer inspection does it become clear that this is not a scientific exhibit. Using familiar materials, which the eye does not decode as such at first glance, Anker interrogates the relationship between the concrete and the abstract of scientific graphicness and cultural codes. Her most recent work, *code.X:genome 2000*, similarly takes up the theme of commonality in the semiotics of art and genetics. Three large-format panels in a flat shade of grey cover the gallery walls almost entirely and fifteen pictures are arranged to form a large field of images. On the floor is an oblong-shaped space containing five hundred letters of grey Plexiglas. In this installation, too, Anker uses signs in which molecular biology is communicated: the letters scattered over the floor are the initial letters of the bases adenine, cytosine, guanine, and thymine, which code genetic information in the polynucleotide chain of DNA, plus an X that represents «junk DNA». Here, Anker continues the sequence of chromosome pairs, some in random constellations against a painterly background and some painstakingly ordered. The arrangement of the chromosomes in vertical columns evokes associations with Chinese characters and underlines their semiotic and ornamental nature. Both the monochrome colouring of the installation and the allusion to the semiotics of the imagery of the life sciences is an overt critique of the notion of reducing the physical body and its perception to pre-determined «code».

The British artist Pam Skelton, who currently teaches at Central Saint Martin's College of Art and Design in London, foregrounds the question of the formation of women's identity in her dialogue with history in the works *As Private as the Law* (1991) and *The X Mark of Dora Newman* (1991–1994).[27] The installation *As Private as the Law* also takes up the theme of chromosomes: sixteen small square panels with sixteen pairs of chromosomes. Each black square with a yellow chromosome pair is followed by a yellow square with a different, black chromosome pair. Behind each of the black and yellow chromosome pairs are shadowy silhouettes of photographs of Myton, the old Jewish area in the city of Hull, and of Drancy, a camp just outside Paris, from where the Germans deported Jews to the concentration camps in Germany. In the nineteenth century, the port of Hull was one of the most important points of entry for immigrants from Northern Europe. Skelton's Jewish ancestors came to Hull from the Ukraine in the 1870s, during one of the waves of immigration of Russians fleeing the pogroms. The focus of the work is the search for the formation of identity within the frame of history and individual destiny. On the one side, the chromosomes refer to the individual, with its unique genetic make-up, and on the other, Skelton points to the social sphere, to places and localities where her ancestors lived, which have made her what she is today. Thus the title, *As Private as the Law,* can be read in two ways: as biological genesis and as a chance trace in the concepts of «laws»; on the one side «natural» biology and on the other the «written word» of the Thora. In *The X Mark of Dora Newman* (1991–1994), Skelton searches for traces of her great grandmother in history. A text fragment is the fragment of history on which a procedure of detection is based. The starting point of the installation is the only surviving written testimony of Dora Newman: the X she signed instead of her name on her daughter's birth certificate in 1886. Mounted at eye level are forty-eight square canvases, each showing a pair of chromosomes, which run around the white walls of the gallery like a ribbon of history. At the centre are two white squares showing a facsimile of the birth certificate; the squares to the left are black and to the right are white. Skelton uses the X mark on the document as an emblem, both as the distinctive individual mark of her ancestor and, in the abstract sense, as the female X chromosome. The double meaning of X stands for the presence and absence of her great grandmother in history, of whom no photograph survives: «…in *The X Mark of Dora Newman,* the X chromosome and the X mark inscribed on the birth certification is both the anonymity and the embodiment of Dora, who has been apparently situated outside of language and outside of representation. The fact that she signed her daughters birth certification in 1886 with a X, the assumption being that she was illiterate. However, as the X mark is the only remaining sign which bears witness to Dora Newman, the status, or rather lack of status, of the female subject in this instance comes into question as a defining factor.»[28]

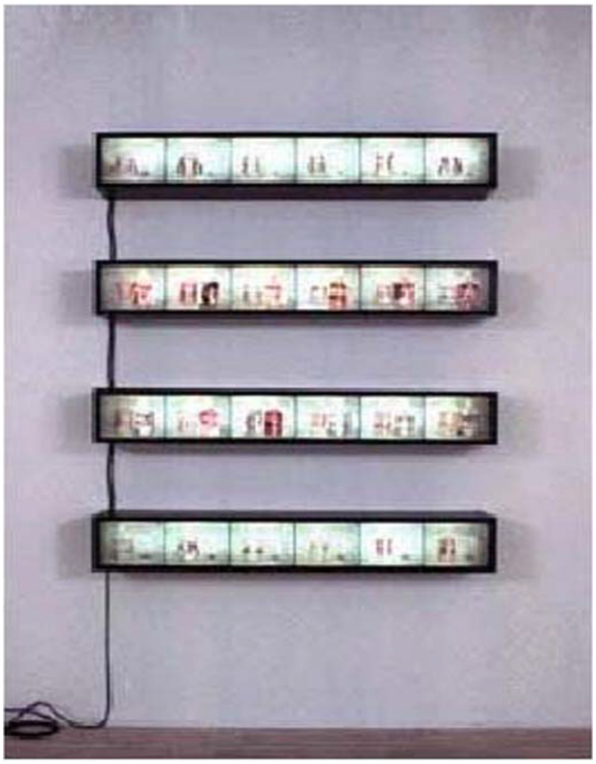

Plate 5: Nell Tenhaaf, In Vitro. (1990)

The Canadian artist Nell Tenhaaf has engaged with the relationship of art and models used by molecular genetics in her work for many years. The installation *In Vitro* (1990) illuminates pairs of chromosomes, which are encased in four wooden light boxes, one above the other, on Plexiglas. Each box is lit from the inside by a lamp and is divided into five compartments, each containing a chromosome pair. The title, *In Vitro*, can be interpreted as a reference to the controversial technologies of reproductive medicine, the *in vitro*-fertilization of human eggs in laboratories and the vision of «test-tube babies», which became a reality in 1978.[29] Tenhaaf's work *The solitary begets herself, keeping all eight cells* (1993)

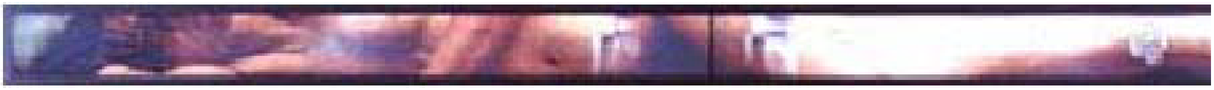

Plate 6: Nell Tenhaaf, The solitary begets herself, keeping all eight cells. (1993)

is also intended as a critique of how women's capability to bear children has been usurped by technology and of the exploitation and control of life by the new life sciences and their inherent power structures.[30] A naked woman is shown in an oblong case of aluminium, scarcely 20 cm high. The body appears cramped and uncomfortable in its long case, evoking Hans Holbein the Younger's Dead Christ as predella in Basle. Scattered over the woman's body are clusters of cells — in twos, fours, and eights. This is a reference to the practice in reproductive medicine of extracting one or two cells from embryos at the eight-cell stage for genetic tests. Such testing, at this very early stage of development, renders eugenic selection possible. The possibilities of present-day reproductive medicine represent a fundamentally new departure in history: until now, humans were born of a mother, there was an undisputed physical relationship between two people, mother and child, which was a central factor of human identity through the fact of birth.[31] In the age of the technical reproducibility of humans, this bond has been broken.

In one of Tenhaaf's early works, where she addresses the visual metaphors of molecular genetics, her criticism takes a completely different direction. *Species Life* (1989) shows two rows of wooden boxes arranged exactly one above the other. Inside are numerous coloured DNA strands of the double helix mounted on Plexiglas and illuminated by lamps. The top row consists of twelve square boxes, positioned at eye-level on the gallery wall without any space in between. The bottom row has two sets of five boxes with an empty space between the sets. The motif of the double helix winds across the divisions of the boxes. A decisive feature of this work is the depiction of the unravelling of the DNA before replication. The two strands separate like nail bombs and jump out of the image space, tearing apart the bonds of «life», and running counter to the elegant appearance of perfect aesthetics embodied by the double helix.

Here Tenhaaf visualises a weakness of the «elegant» model of the double helix, which is not to be underestimated, and draws attention to the problem of the separation of the strands of DNA in the double helix, which is frequently ignored by scientists.[32] The model of DNA's molecular structure in the form of a double helix is not capable of explaining which chemical process is responsible for separating the strands nor where the energy comes from that triggers this process. Shortly after Watson and Crick published their model, it was criticised by prominent scientists. The British geneticist Rosalind Franklin was among the first to raise objections. Since 1947, Franklin had been working on the structure of DNA and her continual refinement of x-ray crystallography led in 1951 to the first revealing technical images of the structure of DNA. In the 1970s, the development of alternative models of the structure of DNA was pursued at the periphery of the scientific discourse; however, these efforts received scant attention.[33] When Watson and Crick formulated their DNA model in the form of a double helix, they were not driven by a striving for «scientific exactitude» alone.[34] They were perfectly aware of the fact that the credibility of a scientific model does not depend exclusively on its scientific exactness but also on its power to convince and its usefulness, both for research and the discourse of the discipline within which it is formulated. Its power to convince is produced within a social and historical context and depends in part on aesthetic features of the model,[35] which, in turn, are subject to differing criteria according to discipline and epoch.[36] However, these are often no longer in evidence after a model has been formulated so that its social and historical construction and conditionality are not obvious.[37]

Whereas artists, such as Suzanne Anker, Pam Skelton, and Nell Tenhaaf, address in their work the representations of scientific models of molecular biology and the act of transforming objects that were formerly in the science domain into vehicles of meaning in quite different areas of knowledge, other artists, such as Eduardo Kac and Joe Davis, take an entirely different direction in their engagement with art and science. Their works use

Plate 7: Nell Tenhaaf, Species Life. (1989)

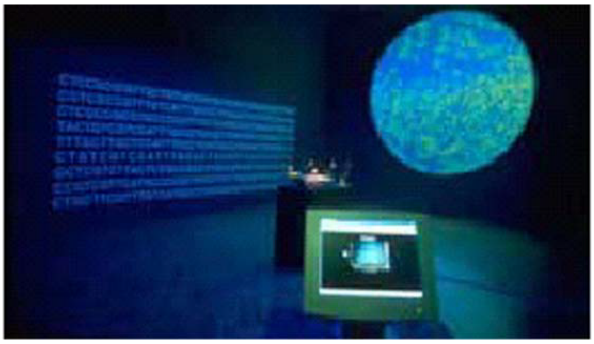

Plate 8: Eduardo Kac, Genesis. (1999), O.K. Center for ContemporaryArt, Linz, Austria, 4.-19. september 1999

real transgenic organisms to address the perpetuation of evolution by humans through creating novel organisms according to aesthetic criteria, which the advent of recombinant DNA technology has now made possible.

TRANSGENIC ART

The Brazilian media artist and theorist, Eduardo Kac, assistant professor of art and technology at the Art and Technology Department of the Art Institute of Chicago, operates at the interface of art and genetic engineering in his recent projects *GFP K-9* (1998), a bioluminescent dog, *GFP Bunny* (2000), a green-glowing rabbit, and the installation *Genesis* (1998–1999). With these works, Kac puts up a new art form for debate: the concept of Transgenic Art[38] Kac's early work focussed primarily on telecommunication and telepresence and, specifically, the question of the perception of reality and the communication of presence.

By creating transgenic animals and integrating them domestically and socially, it is Kac's declared intention to draw attention to the cultural effects and implications of a technology that is not accessible visually and bring these to the public's attention for debate. Using biotechnology, Kac transfers synthetic genes to organisms and natural genes from one species to another.[39] Projected is the creation of originals, unique organisms. In his installation *Genesis*, Kac attempts to make biological processes and technological procedures visible, which for years now have been standard practice in research laboratories. In a dark room, a brightly illuminated petri dish stands on a pedestal. A video camera,[40] which is positioned above it, projects an oversize image of the dish onto the wall. Ultraviolet light falls onto the petri dish and the intensity of the light can be controlled by the visitor via a computer. This can be done either in the gallery or via the Internet. In this way the users can influence the processes of replication and interaction of the bacteria in the petri dish and observe these in the magnified projection on the wall or on the Internet — processes, which normally can only be seen under a microscope. Thus the role of the observer is enhanced to that of active participant, who is able to intervene in the processes and influence the course of the work's presentation.

The focus of the installation is a synthetic gene created by Kac, a so-called «artist's gene». First, he translated a sentence from the biblical Book of Genesis, the First Book of Moses, into Morse code and then converted it into DNA base pairs according to principles of conversion developed especially for this work. Kac chose the Morse code because it was first used in radiotelegraphy at the beginning of the information age and, thus, stands at the genesis of global communication[41] The synthetic gene was cloned into plasmids and then transferred to bacteria, where it synthesises a new protein molecule. Two mutations of green fluorescent protein create two different bacteria with different spectral properties. This process, which would normally take place only within a laboratory, Kac has transferred to an art gallery. With his Transgenic Art, Kac wishes to draw attention to the cultural implications of biotechnology and its possibilities for transforming and manipulating life. However, the aesthetics of this artistic presentation overwhelm the demonstration of the laboratory's function as the place where knowledge is produced. Transgenic organisms have been produced in laboratories now for over twenty years and the first bioluminescent mice were bred in 1995. When, in 2000, Kac created his second transgenic artwork, *Bunny 2000,* a biolumi-

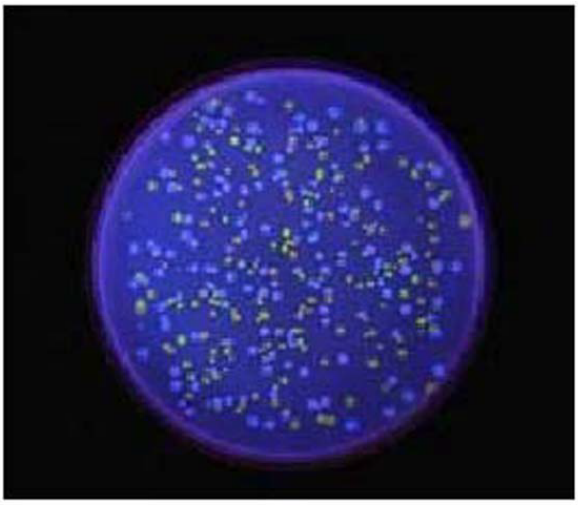

Plate 9: Eduardo Kac, Genesis. (1999), detail.

Plate 10: Eduardo Kac, Bunny 2000. (2000)

nescent rabbit named Alba, researchers had already created the first primate carrying a green fluorescent protein, a monkey named Andi. Kac may use advanced biotechnology in his work, yet the metaphors surrounding this technology and the interplay between cultural norms and technical development remain unaddressed.

A BRIDGE BETWEEN THE «TWO CULTURES»

Under the title «'Genetic art' Builds Cryptic Bridge between Two Cultures», in November 1995 the science journal *Nature* reported on an exhibition held at Harvard University in Cambridge, Massachusetts. Joe Davis, artist in residence at the Massachusetts Institute of Technology (M.I.T.), intended to exhibit a strain of *Escherichia coli* bacteria, which he had developed in the period December 1993 to January 1994 in collaboration with the Laboratory of Molecular Structure at M.I.T. Biology and the Burghardt Wittig Laboratory of the Free University of Berlin. Davis wanted to present these deep-frozen recombinant *E. coli* bacteria on the premises of the university. The university's security department, however, regarded this plan as constituting a serious safety risk and demanded that the artist treat the genetically manipulated organisms with formaldehyde and chloroform. Although an artist may make use of state of the art genetic engineering techniques, ultimately, it is not the artist who decides on the form of their presentation; in this case, it was the security department of the university. Seemingly this exhibition suspended the boundaries between art and science; bridged the gap between the sharply bipolar cultures for the time being. However, the intervention of the university's security department brought into sharp focus just where the dividing line between these two cultural levels lies.

A few years before, in his project *Microvenus* Joe Davis had focussed on DNA as the carrier of non-biological informatio[42] In collaboration with genetic engineers, Davis designed a molecule and transferred it to an organism, live *E. coli* bacteria. Thus *Microvenus* is a recombinant organism that contains many copies of a molecule created by an artist. As the starting point for his work, Davis chose an old Germanic symbol for life and the female earth. A special conversion programme translated the symbol into DNA bases. Once these artistically engineered elements of DNA are incorporated into bacteria, they can be expressed unchanged over a long period of time and are resilient enough, even under extreme conditions (for example, in space), to replicate a very great number of times. Because of the possibilities offered by bacteria as a long-term storage medium,, Davis envisaged using the DNA of *Microvenus* as an interstellar medium of communication.

The aestheticisation of genetic engineering, as practiced by Eduardo Kac and Joe Davis in their bioartworks, however, appears to lead to a playing down of the risks and acceptance of biotechnology rather than critical reflection for neither an assessment of this technology's impact nor a discussion of the risks involved take place. By availing themselves of the latest biotechnological innovations and their industrial exploitation, an art trend

Plate 11: Eduardo Kac with Bunny 2000 (2000)

like Transgenic Art has pretensions to constituting a force for innovation and social relevance and, at the same time, valorises a socially controversial technology. Eduardo Kac allows the telepresent observer to play «interactively» with the «code of life» and in his large-dimensional multimedia works stages biological processes within the space between the poles of the new media and biotechnology.

Artists like Eduardo Kac and Joe Davis, who operate at the interface of art, science, and new technologies understand their artistic practice as building a bridge between two cultures, which are considered as diametrically opposed, and they appear to move comfortably in this «in between» or Third Culture.[43] The notion of a Third Culture was proposed by C.P. Snow in 1963 in the second, revised edition of his book «The Two Cultures»,[44] first published in 1959, in an additional essay entitled «The Two Cultures: A Second Look.»[45] With this concept, he attempted to delineate the interface between the natural sciences and the arts and humanities, which might serve to close the yawning gap between these two cultures. Today, there are artists who consider themselves «as researchers»[46] and whose work finds recognition in scientific circles and, moreover, the question as to what extent the images produced by science should be considered as art is a subject for serious debate.[47] In the meantime, both science and art are attributed with performing the function of a bridge, which is supposed to promote a dialogue between the two cultures.[48] However, the question is: who enters into a dialogue with whom here? In the natural sciences, the idea has long since gained common currency that aesthetic considerations, which play a necessary part in the visualisation of scientific findings, by no means detract from interest in the science presented. Today, aesthetic considerations no longer represent a contradiction to the findings presented but rather are an integral part of science, for today's scientist is not a «coldly registering thinking apparatus» any more, the target of Friedrich Nietzsche's polemic.[49]

Endnotes

1 Producing Art, ed. Caroline A. Jones and Peter Galison, London, New York: Routledge –207.

2 Zur symbolischen Bedeutung des menschlichen Genoms. In: Die Eroberung des Lebens. Technik und Gesellschaft an der Wende zum 21. Jahrhundert, ed. Lisbeth N. Trallori, Vienna: Verlag für Gesellschaftskritik 1996: p. 138ff.

3 See Ludger Weß: Die Träume der Genetik. In: Die Eroberung des Lebens. Technik und Gesellschaft an der Wende zum 21. Jahrhundert, ed. Lisbeth N. Trallori, Vienna: Verlag für Gesellschaftskritik 1996: p. 138ff.

4 Künstliches Leben»; «GameGrrl. Abwerten biotechnologischer Annahmen» Zürich/Munich1994; «Frankensteins Kinder» Zürich 1997; «Out of Sight: Imaging/Imagining Science» Santa Barbara 1998; «Tenacity: Cultural Practices in the Age of Information- and Biotechnology» New York/Zürich 2000; «Paradise Now», New York 2000; «New Life», Casula 2000; «The 8th New York Digital Salon 2000», New York 2000; «Unter der Haut. Transformationen des Biologischen in der zeitgenössischen Kunst», Duisburg 2001.

5 George Gessert: Notes on genetic art. *Leonardo*–211; Ellen K. Levy: Contemporary art and the genetic code: New models and methods of representation. *Art Journal. Contemporary Art and the Genetic Code*–24; Ellen K. Levy: Repetition and the scientific model in art. *Art Journal. Contemporary Art and the Genetic Code*–84; Robert Shapiro: DNA, art, and hereafter. *Art Journal. Contemporary Art and the Genetic Code*–78; Georg Gessert: Eine Geschichte der DNA-involvierenden Kunst. –244. Vienna, New York: Springer 1999; Ingeborg Reichle: Kunst und Biomasse: Zur Verschränkung von Biotechnologie und Medienkunst in den 90er Jahren. *kritische berichte*–33.

6 Cf. Ellen K. Levy and David E. Levy: Monkey in the middle: Pre-Darwinian evolutionary theory and artistic creation. *Perspectives in Biology and Medicine*–106.

7 Cf. Martin Kemp: Visualizations. The Nature Book of Art and Science. Berkeley, Los Angeles: University of California Press 2000; Stephen Jay Gould: The shape of life. *Art Journal. Contemporary Art and the Genetic Code*–46; Alfred J. Tauber, ed.: The Elusive Synthesis: Aesthetics and Science. Dordrecht: Kluwer 1996; Deane W. Curtin, ed.: The Aesthetic Dimension of Science. New York: Philosoph. Library 1982; Robert Root-Bernstein: Visual thinking: The art of imagining reality. *Transactions of the American Philosophical Society* –67; Judith Wechsler, ed.: On Aesthetics in Science. Cambridge, Mass.: MIT Press 1978.

8 Charles R. Darwin: On the Origin of Species by Means of Natural Selection. London: John Murray 1859.

9 Charles R. Darwin: The Descent of Man. London: John Murray 1871.

10 Ernst Haeckel: Kunstformen der Natur. Leipzig, Vienna: Bibliogr. Institut 1904.

11 Cf. Sara Lynn Henry: Form creating energies: Paul Klee and physics. *Arts Magazine*–118.

12 ’’Arcy Thompson: The Scholar Naturalist. Oxford: Oxford University Press 1958 and Stephen Jay Gould: Ontogeny and Phylogeny. Cambridge, Mass ; London : Belknap Press of Harvard University Press 1977.

13 See Martin Kemp: Doing what comes naturally: Morphogenesis and the limits of the genetic code. *Art Journal. Contemporary Art and the Genetic Code*–32.

14 Hugo de Vries: Das Spaltungsgesetz der Bastarde. *Berichte der Deutschen Botanischen Gesellschaft*–’s Regel über das Verhalten der Nachkommenschaft der Rassenbastarde. *Berichte der Deutschen Botanischen Gesellschaft*–168; Erich von Tschermak: Über künstliche Kreuzung bei *Pisum sativum*. *Berichte der Deutschen Botanischen Gesellschaft*–239.

15–1884) published his first conclusions on heredity in plants, Versuche über Pflanzen-Hybriden (Experiments in Plant Hybidization), which is acknowledged as the founding text of genetics: see Evelyn Fox Keller: The Century of the Gene. Cambridge, MA: Harvard University Press 2000.

16Over a period of many years, Mendel experimented with the garden pea and other plants before he presented his findings in 1865 to the Naturforschender Verein in Brünn (Brno) at two meetings. ’s journal *Verhandlungen des Naturforschenden Vereins*; see Robin Marantz Henig: Der Mönch im Garten. Die Geschichte des Gregor Mendel und die Entdeckung der Genetik. Berlin: Argon Verlag 2001, p. 8ff.

17–After 1900, many scientists from a variety of disciplines went into research on the Mendelian laws of heredity and established the field of experimental genetics. In 1906, William Bateson (1861-1926) coined the term genetics. See Werner Sohm: Hugo de Vries (1848-1935). In: Darwin & Co. Eine Geschichte der Biologie in Portraits, ed. Ilse Jahn and Michael Schmitt, vol. 2, p. 18ff. Munich: Verlag C.H. Beck 2001.

18 Garland Allen: T.H. Morgan and the split between embryology and genetics 1910-1926. In: A History of Embryology, ed. T.J. Horder, I.A. Witkowski, and C.C. Wylie. Cambridge: Cambridge University Press 1986,p. 114; see also pp. 46-113

19 Cf. Evelyn Fox Keller: Refiguring Life. Metaphors of Twentieth Century Biology. New York: Columbia University Press 1996.

20 In 1910, T.H. Morgan (1866-1945) at Columbia University, New York, defined the main properties of heredity and formulated the „laws« of genetics.With his proof of the linear arrangement of genes on the chromosomes, Morgan founded genetics, which represented a new interpretation of Mendelian laws of heredity in terms of the theory of chromosomes.

21 Thomas Hunt Morgan: The Relation of Genetics to Physiology and Medicine. In: Nobel Lecture, Les Prix Nobel en 1934, Stockholm: 1935.

22 Evelyn Fox Keller: The Century of the Gene. Cambridge, Mass.: Harvard University Press 2000, p. 11.

23 Bruno Latour: Science in Action. How to Follow Scientists and Engineers through Society. Cambridge, Mass.: Harvard University Press 1994, p. 1.

24 In 1990, U.S. government bodies launched a billion dollar programme with an international network of collaborators to sequence the entire human genome. However, in early April 2000, J. Craig Venter, geneticist and president of the company, Celera Genomics, anounced to the Energy Committee of the U.S. Congress that his company had succeeded in sequencing the first human genome. This news sparked a dramatic run on the shares of biotechnology firms and triggered numerous debates on international patent legislation, ethical concepts in the life sciences, and the future of humankind itself.

25 In 1994, Suzanne Anker curated one of the first exhibitions on the theme of art and genetics: «Gene Culture: Molecular Metaphor in Contemporary Art,» Fordham College Plaza Gallery, Lincoln Center, New York.

26 See the essays by Suzanne Anker: Gene culture. Molecular metaphor in visual art. *Leonardo*–375; Cellular archaeology. *Art Journal. Contemporary Art and the Genetic Code* 55 (1) 1996: 33.

27 Cf. Pam Skelton: Questions of identities. In: Old Boys Network (ed.): Next Cyberfeminist International, Hamburg: b_books verlag –35; Rosemary Betterton: An Intimate Distance. Women, Artists and the Body. London: Routledge 1996, p. 172 ff.

28 Pam Skelton: Questions of identities. In: Old Boys Network (ed.): Next Cyberfeminist International, Hamburg: b_books verlag 1999, p. 34.

29 In July 1978, the first «test-tube baby» was born in England. Today, *in vitro*-fertilisation is a standard method for treating certain forms of infertility.

30 See Susanne Schultz: Selbstbestimmtes Technopatriarchat? Sackgasse einer immanenten feministischen Kritik an den neuen Reproduktionstechnologien. In: geld.beat.synthetik. Abwerten bio/technologischer Annahmen, ed. Susanne Schultz, pp. –95. Berlin, Amsterdam: Edition ID-Archiv, 1996.

31 Helga Satzinger: In-Vitro-Befruchtung, Embryonenforschung, Keimbahneingriffe. Zur Logik medizinischer Rechtfertigungsethik. In: Grenzverschiebungen: politische und ethische Aspekte der Fortpflanzungsmedizin, ed. Gabriele Pichlhofer, Gen-Ethisches Netzwerk, p. 13. Frankfurt am Main: Mabuse 1999.

32 Robert Root-Bernstein: Do we have the structure of DNA right? Aesthetic assumptions, visual conventions, and unsolved problems. *Art Journal. Contemporary Art and the Genetic Code* 55 (1) 1996: 53ff.

33 Independently, two teams of researchers developed and published models of DNA, which were incompatible with the Watson-Crick model of a dextrorotatory double helix. One team came from the University of Canterbury in Christchurch, New Zealand (Gordon A. Rodley, R.H.T. Bates, Clive Rowe), who had run into problems with the double helix model during observations of the replication of circular DNA. The second team was headed by V. Sasisekharan and N. Pattabiraman of the Indian Institute of Science in Bangalore.

34 See Helen Longino: Natur anders sehen: Zur Bedeutung der Geschlechterdifferenz. In: Vermittelte Weiblichkeit: Feministische Wissenschafts- und Gesellschaftstheorie, ed. Elvira Scheich, pp. 292-310; here p. 306f. Hamburg: Hamburger Edition Institut für Sozialforschung 1996.

35 On the popularity and aesthetics of the double helix in molecular biology around 1950, see Robert Root-Bernstein: Do we have the structure of DNA right? Aesthetic assumptions, visual conventions, and unsolved problems. *Art Journal. Contemporary Art and the Genetic Code* 55 (1) 1996: 48.

36 Martin Kemp: Visualizations. The Nature Book of Art and Science. Berkeley, Los Angeles: University of California Press 2000.

37 In this connection, Donna Haraway has pointed out that textbooks and research reports are written in a style that no longer reveals the research behind the facts but rather in a «bare style» presents «bare facts». –389. Hamburg: Hamburger Edition Institut für Sozialforschung 1996.

38 Eduardo Kac: Transgenic Art. *Leonardo Electronic Almanac* 6 (11) 1998.

39 Eduardo Kac: Transgene Kunst. In: Ars Electronica 99. LifeScience, ed. Gerfried Stocker and Christine Schöpf, p. 296. Vienna, New York: Springer 1999.

40 With video microscopes and computer-generated images, Kac is using standard laboratory technologies, which have entered into a most fruitful alliance with molecular genetics. –76. Cologne: DuMont, 1998.

41 Eduardo Kac: Genesis. In: Gail Wight «Spike», Eduardo Kac «Genesis», exhibition catalogue. Linz: O.K. Center for Contemporary Art 1999, p. 45.

42 Joe Davis: Microvenus. *Art Journal. Contemporary Art and the Genetic Code*—251. Vienna, New York: Springer 2000.
43 More and more artists of the contemporary media art scene, who use new communications technology and processes from the life sciences as material and medium in their work, see themselves as a bridge between the two poles; see Victoria Vesna: Toward a third culture: Being in between. *Leonardo*–125: «Our work depends largely on an active dialogue with scientists and humanists while performing the important function of a bridge» (p. 121).
44 C.P. Snow: Two Cultures. Cambridge: Cambridge University Press 1959.
45 C.P. Snow: The Two Cultures: A Second Look. In: C.P. Snow: The Two Cultures and the Scientific Revolution. Cambridge: Cambridge University Press 1963, p. 53.
46 Christa Sommerer and Laurent Mignonneau (eds.): Art @ Science. Vienna: Springer, 1998.
47 –119. Stuttgart: Friedrich Frommann Verlag, 1994.
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49 –119. Stuttgart: Friedrich Frommann Verlag, 1994.Bibliographie

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